GENESIS

SEARCH FOR ORIGINS

Presented at:

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By:

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Jet Propulsion Laboratory / NASA

Presentation Outline

Part 1: Portrait of the Mission

Part 2: Science by a Non-Scientist

Part 3: Treasure Hunting - Sample Curation & Analysis Plans

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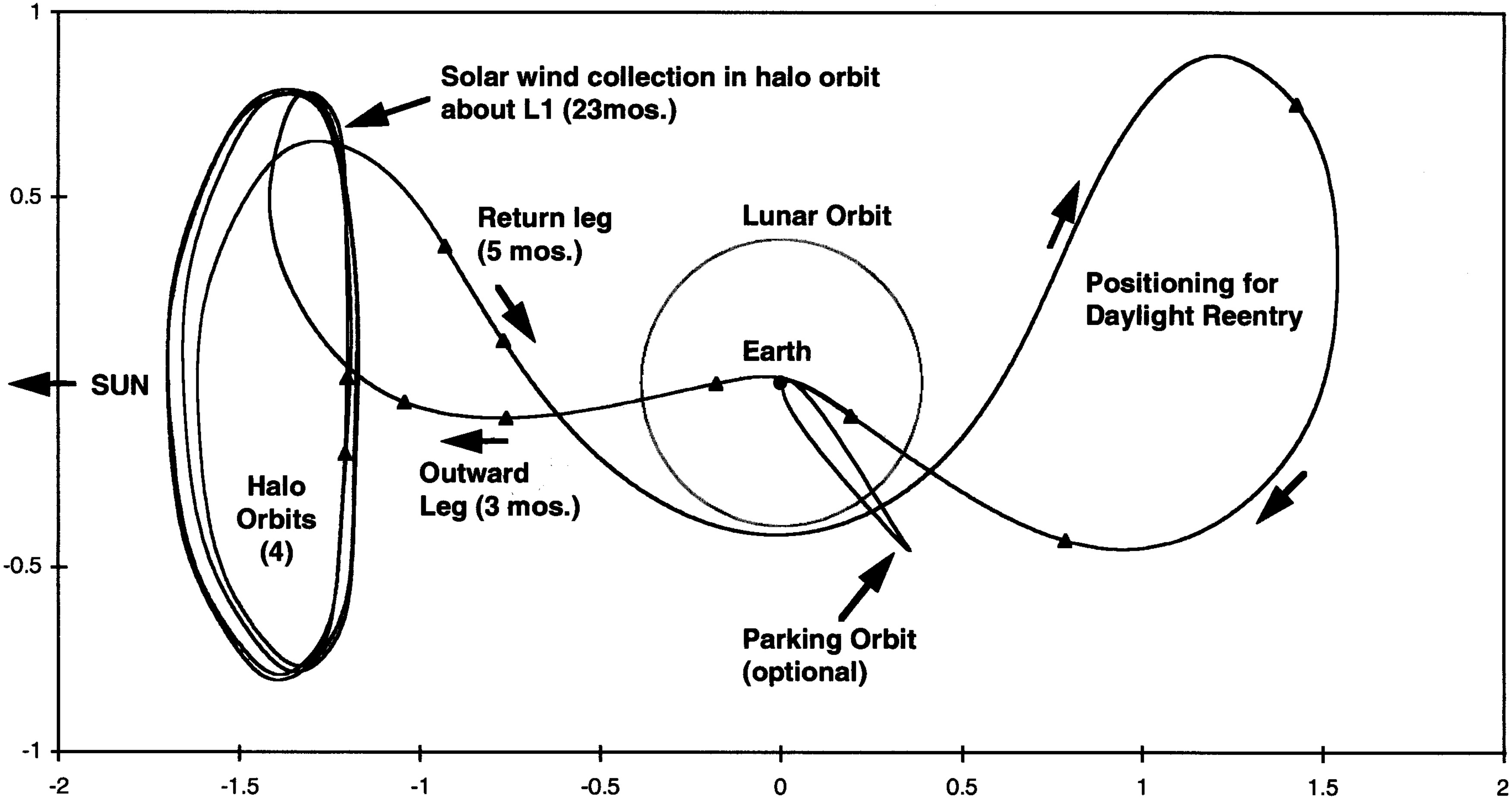
Tracing The Genesis Mission



Millions of Kilometers

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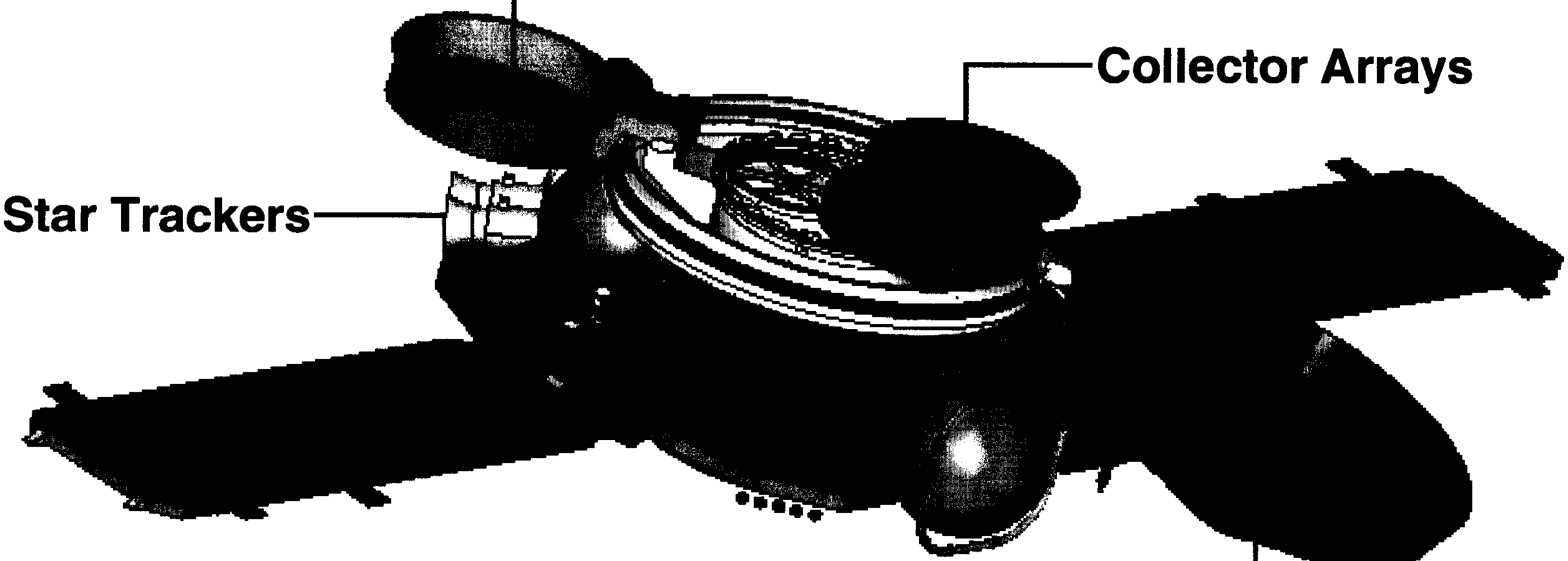
Flight System Science Config'n - Top



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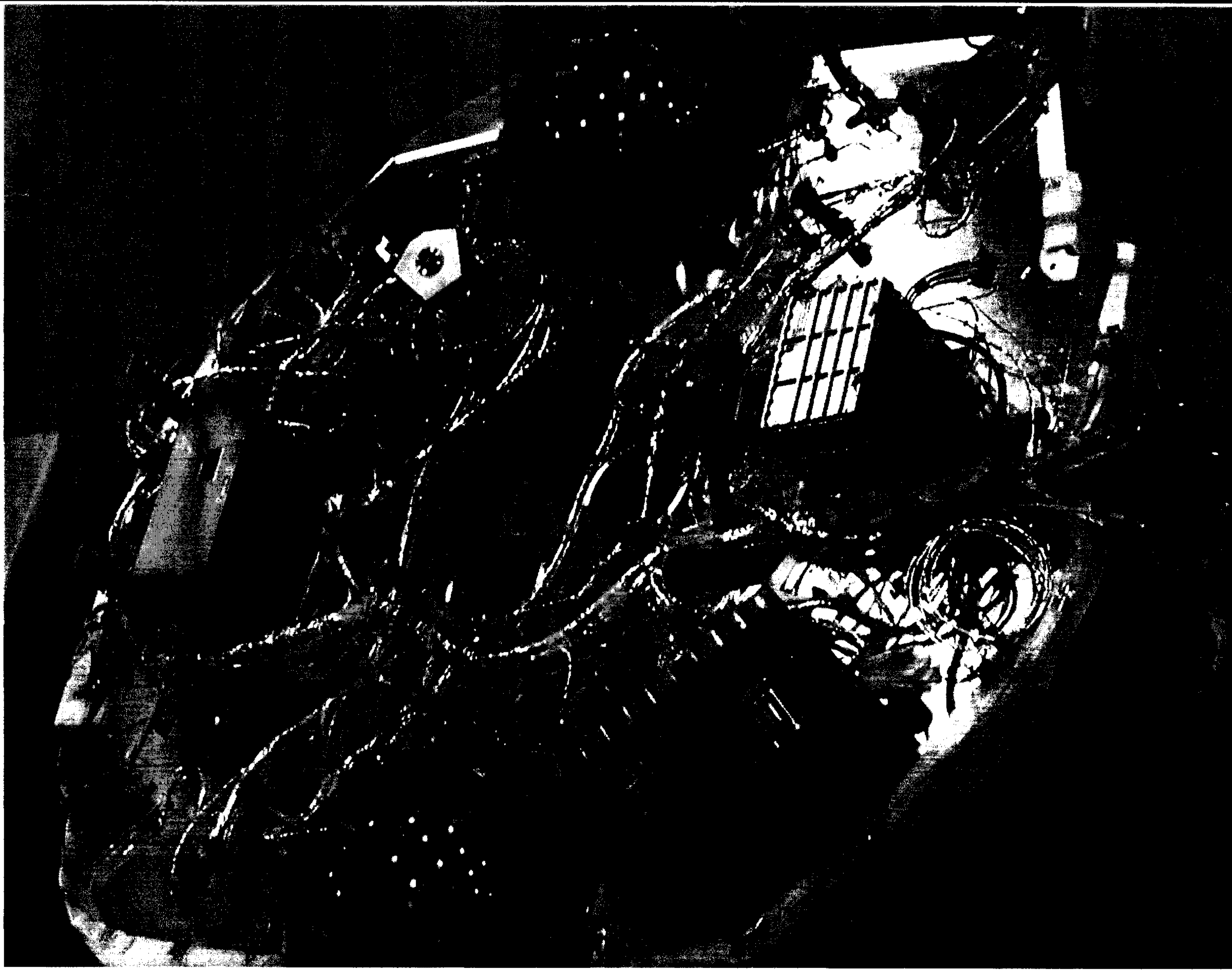
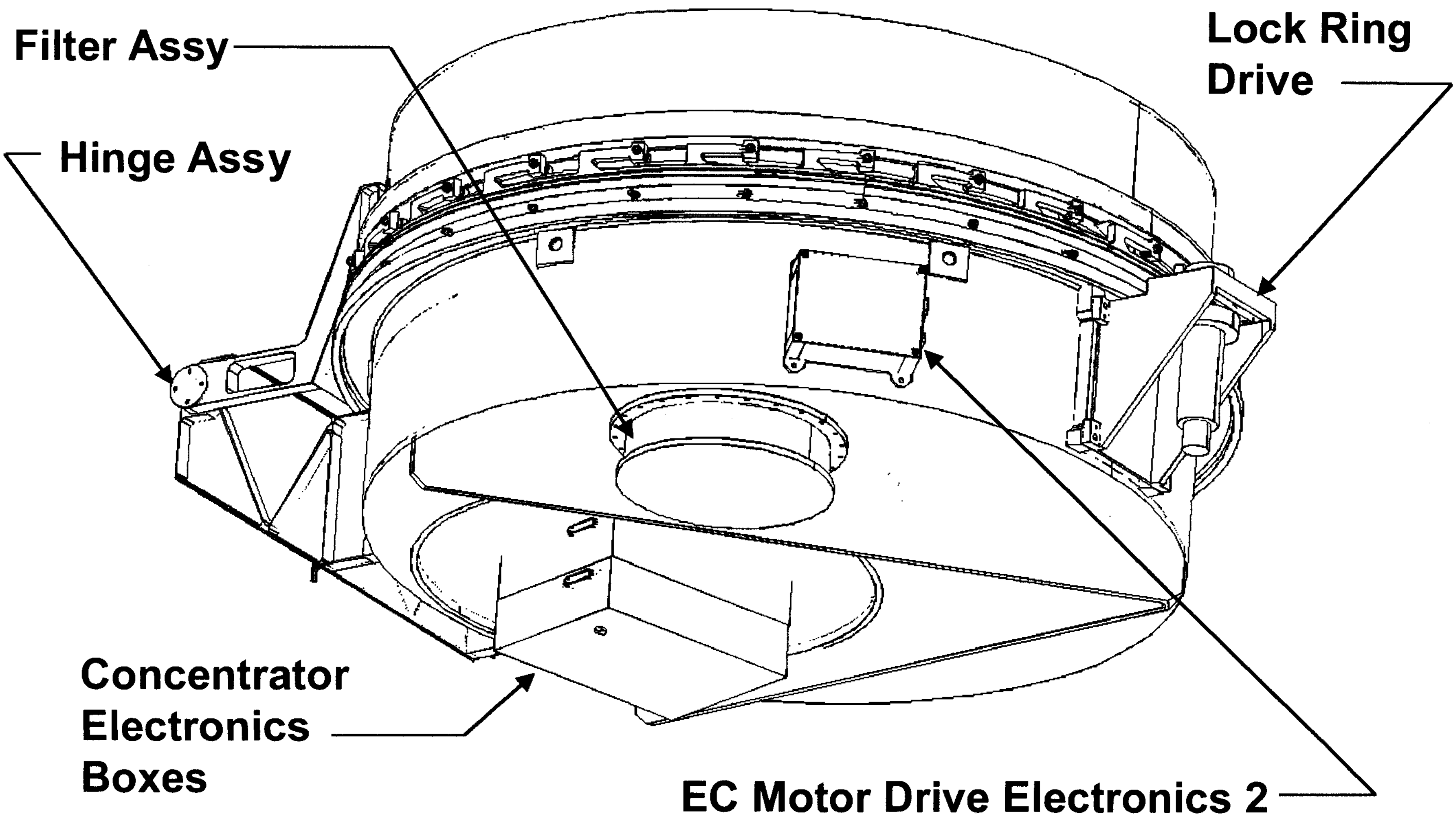
Spacecraft Deck +X



Integrated Canister CAD Model



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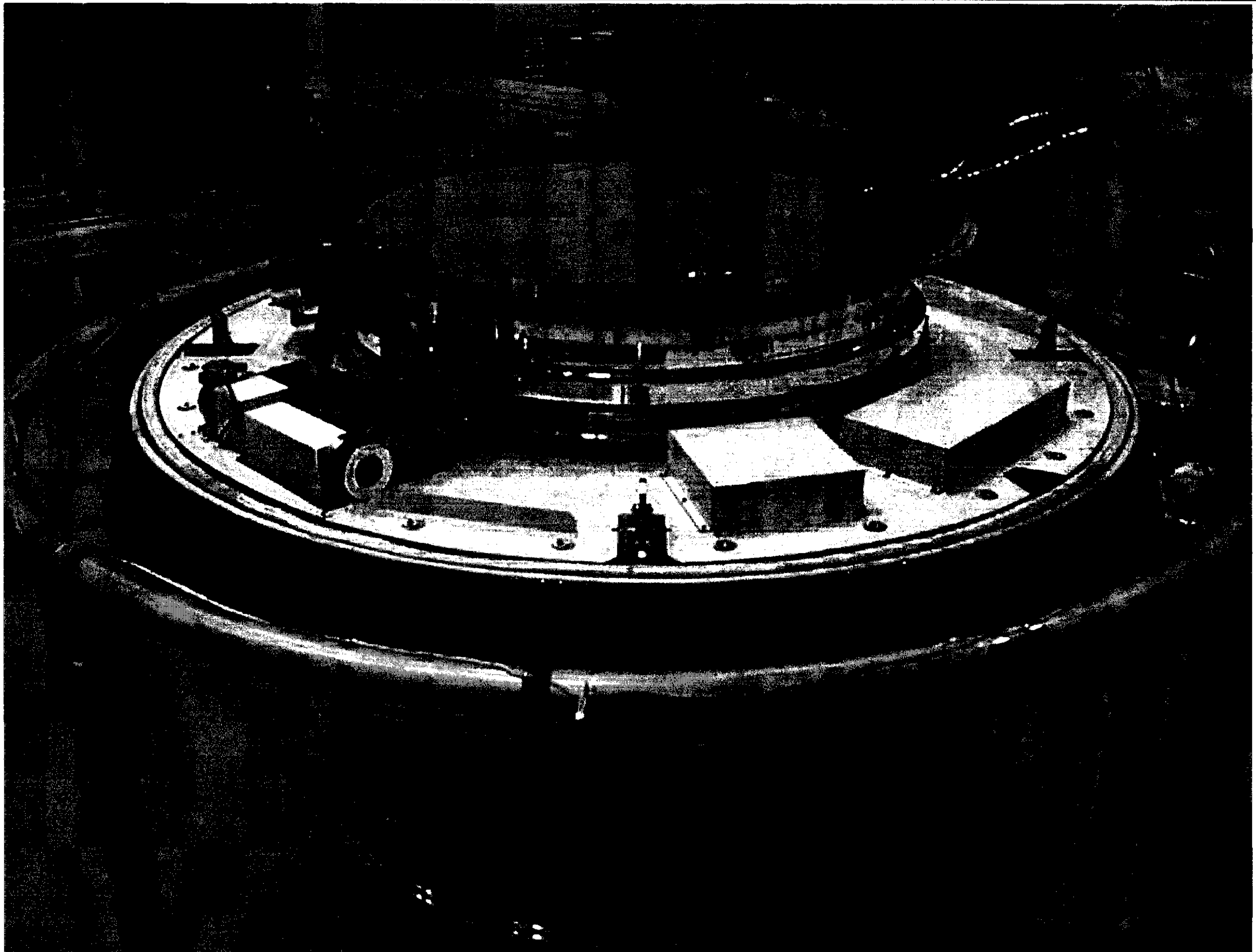
EM CANISTER INTEGRATED TO SRC



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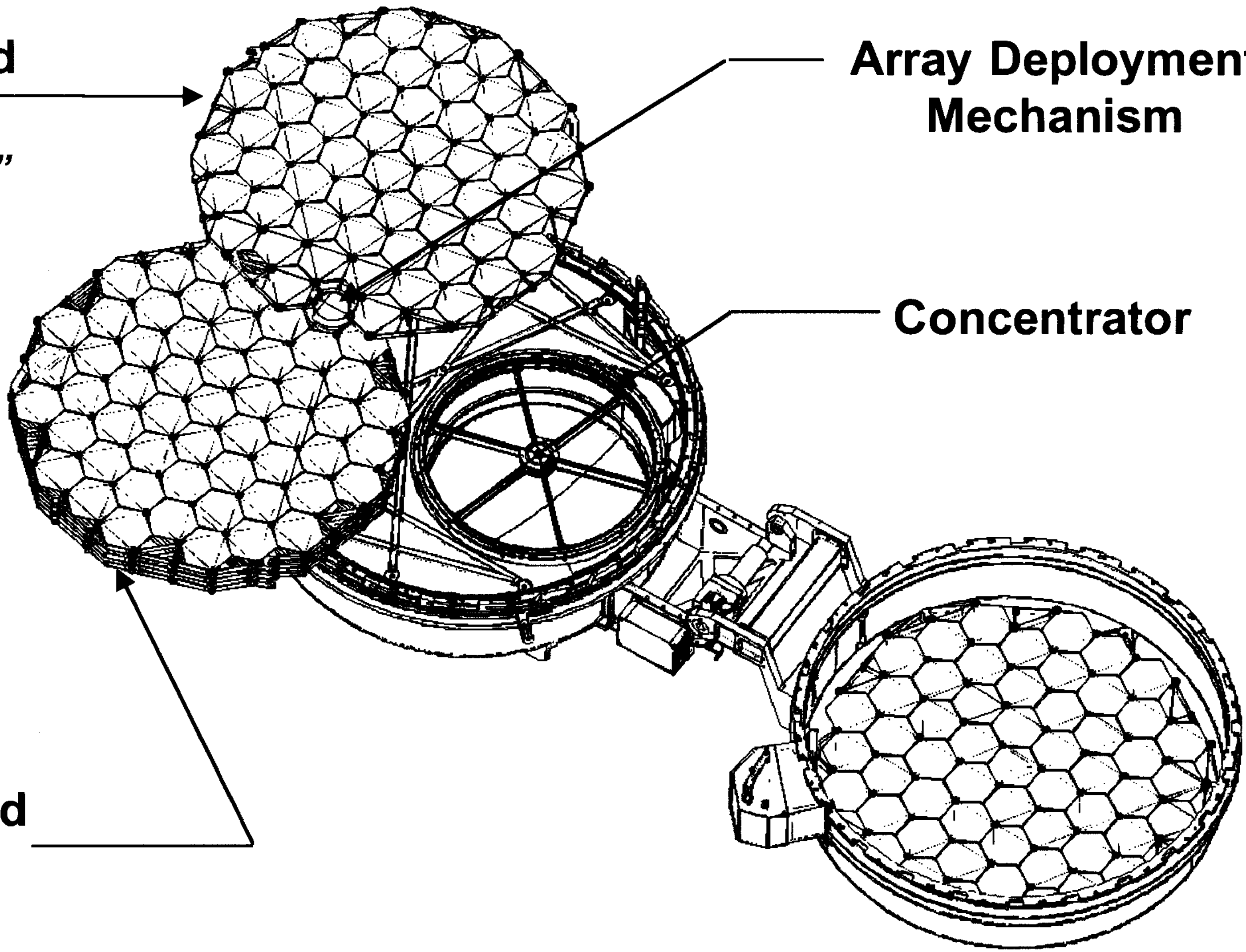
Integrated Canister Deployed



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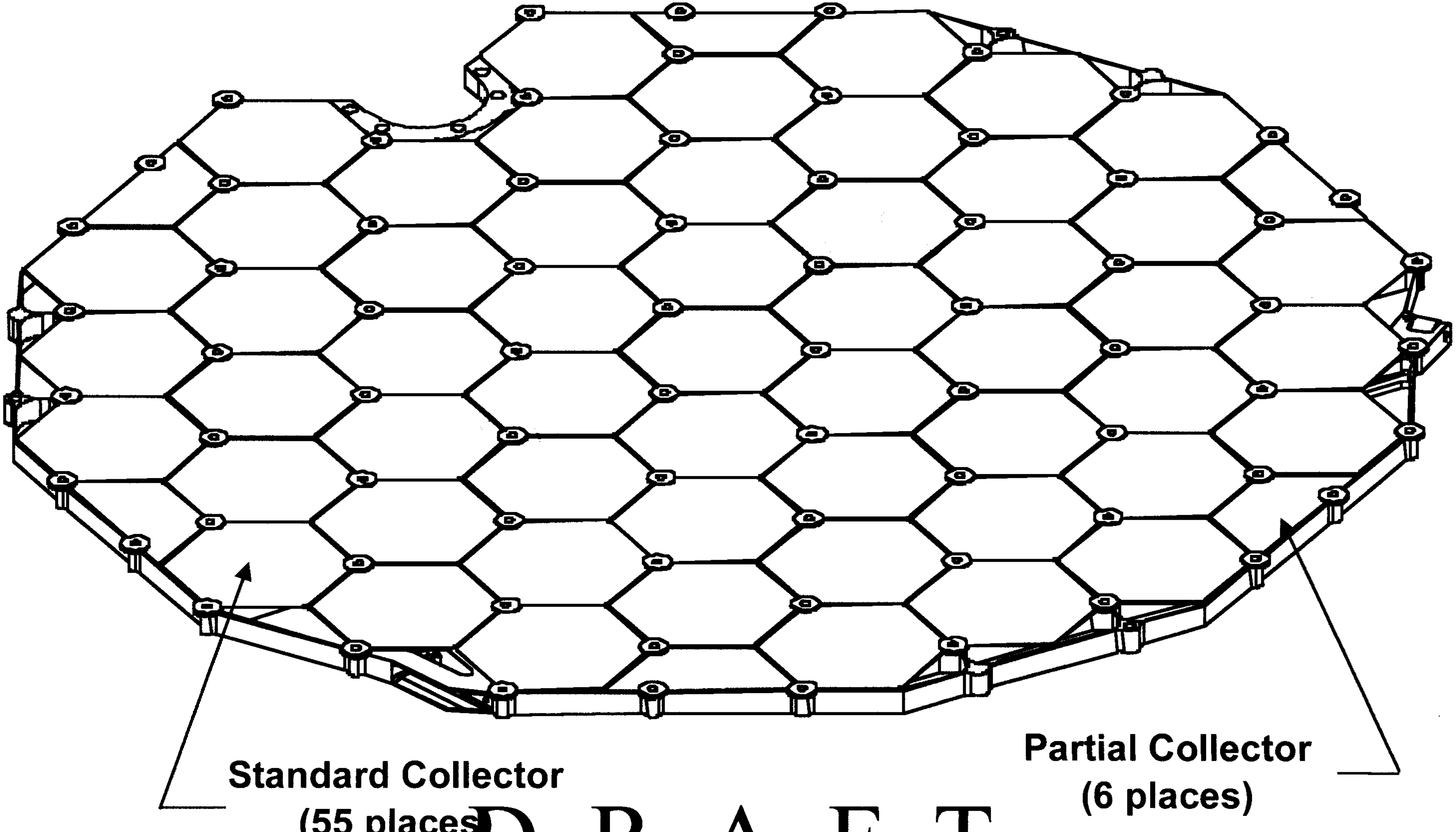
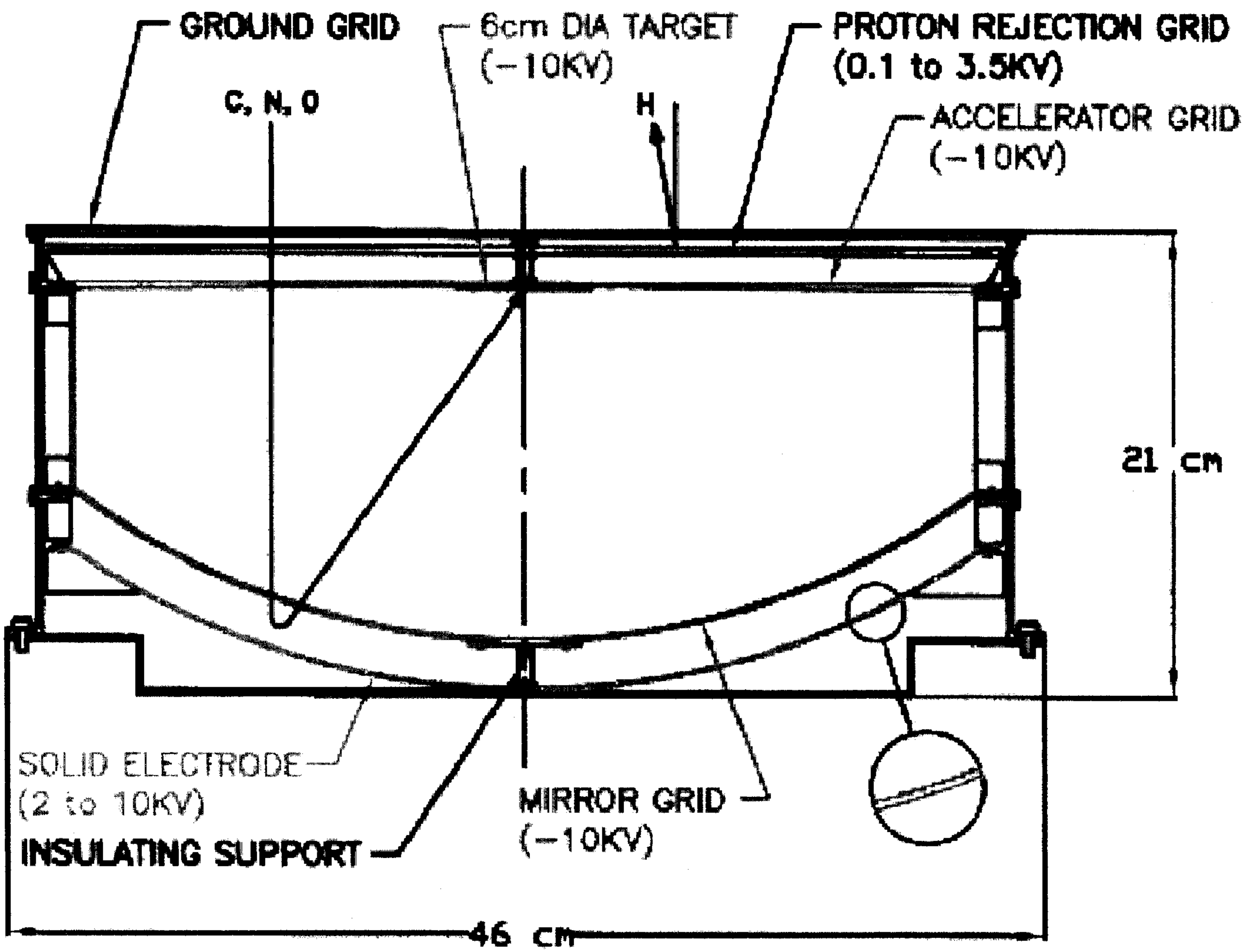
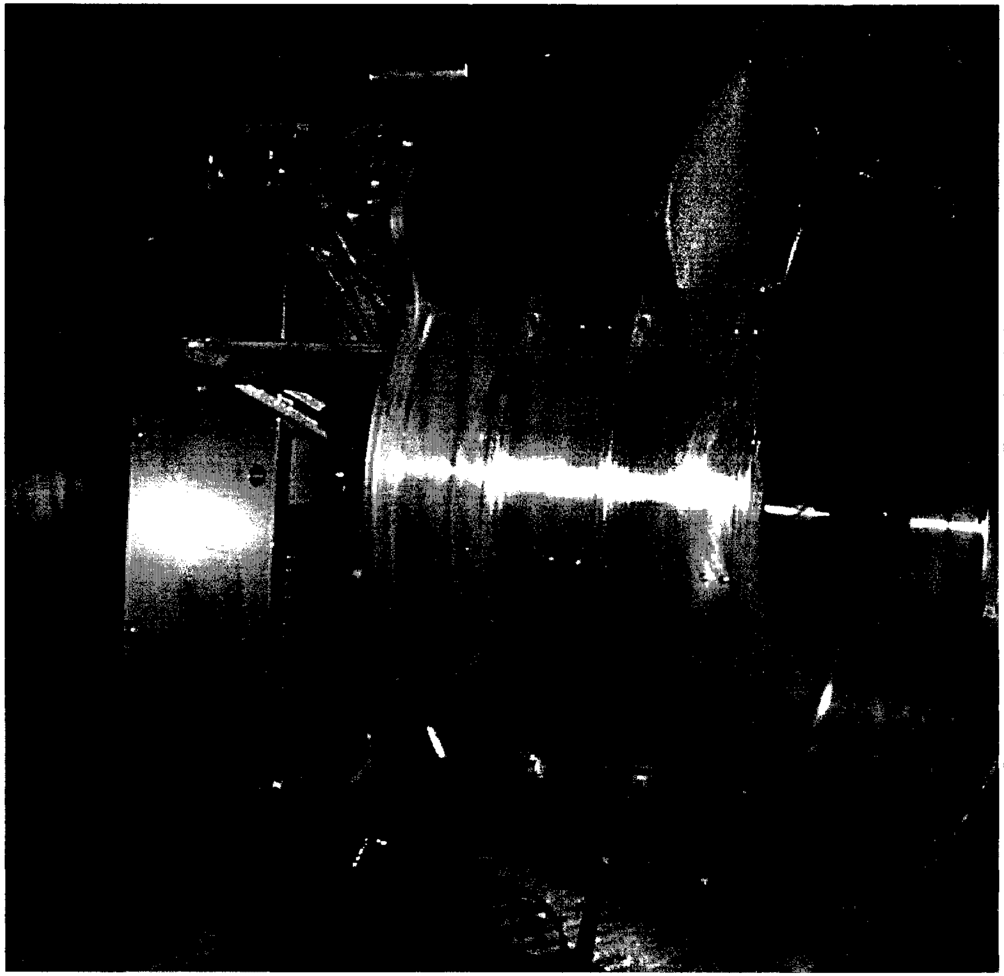
Array Assembly Including Partial Collectors



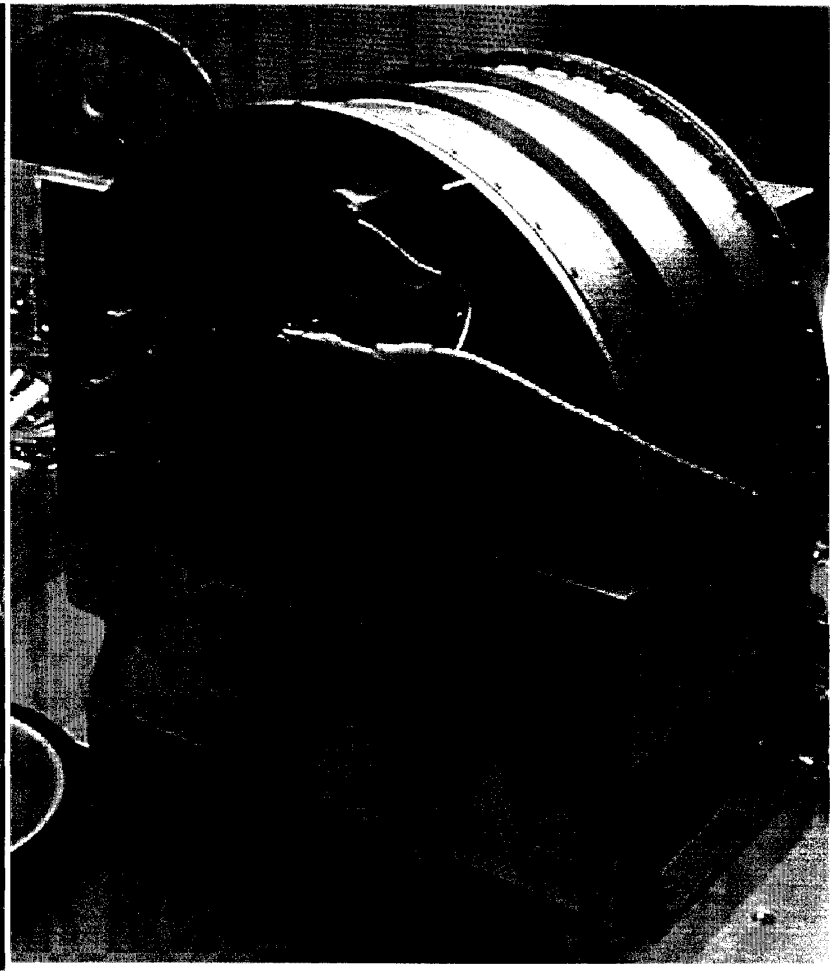
Concentrator Cross-section



PAYLOAD - LANL



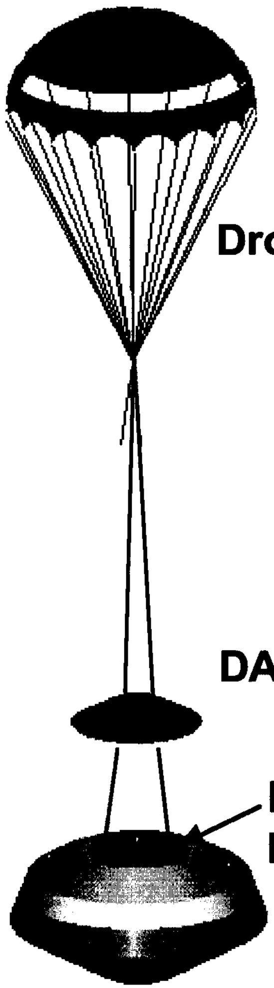
Concentrator



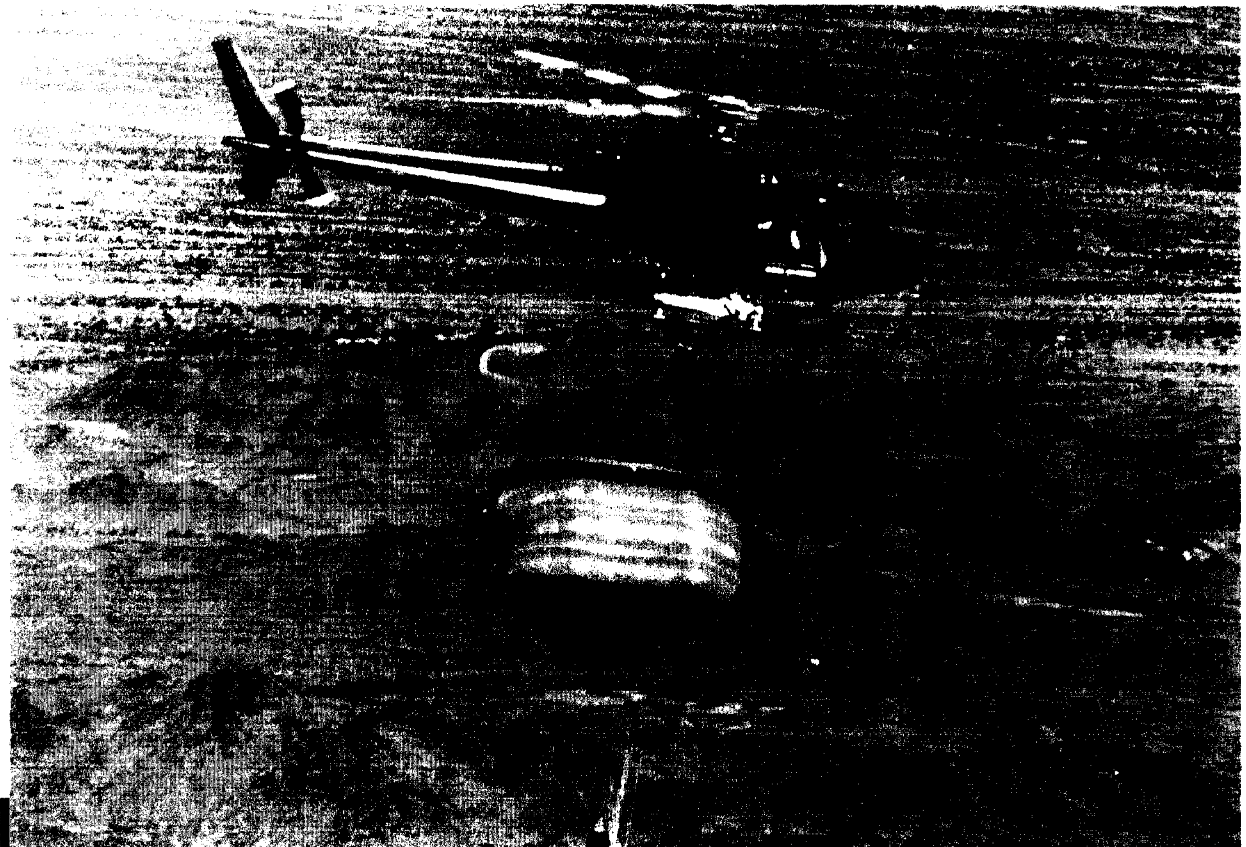
Genesis Electron Monitor (GEM)

Mid-Air Retrieval of SRC

DACS/Drogue Separation



- Mid-air Retrieval Successfully Demonstrated



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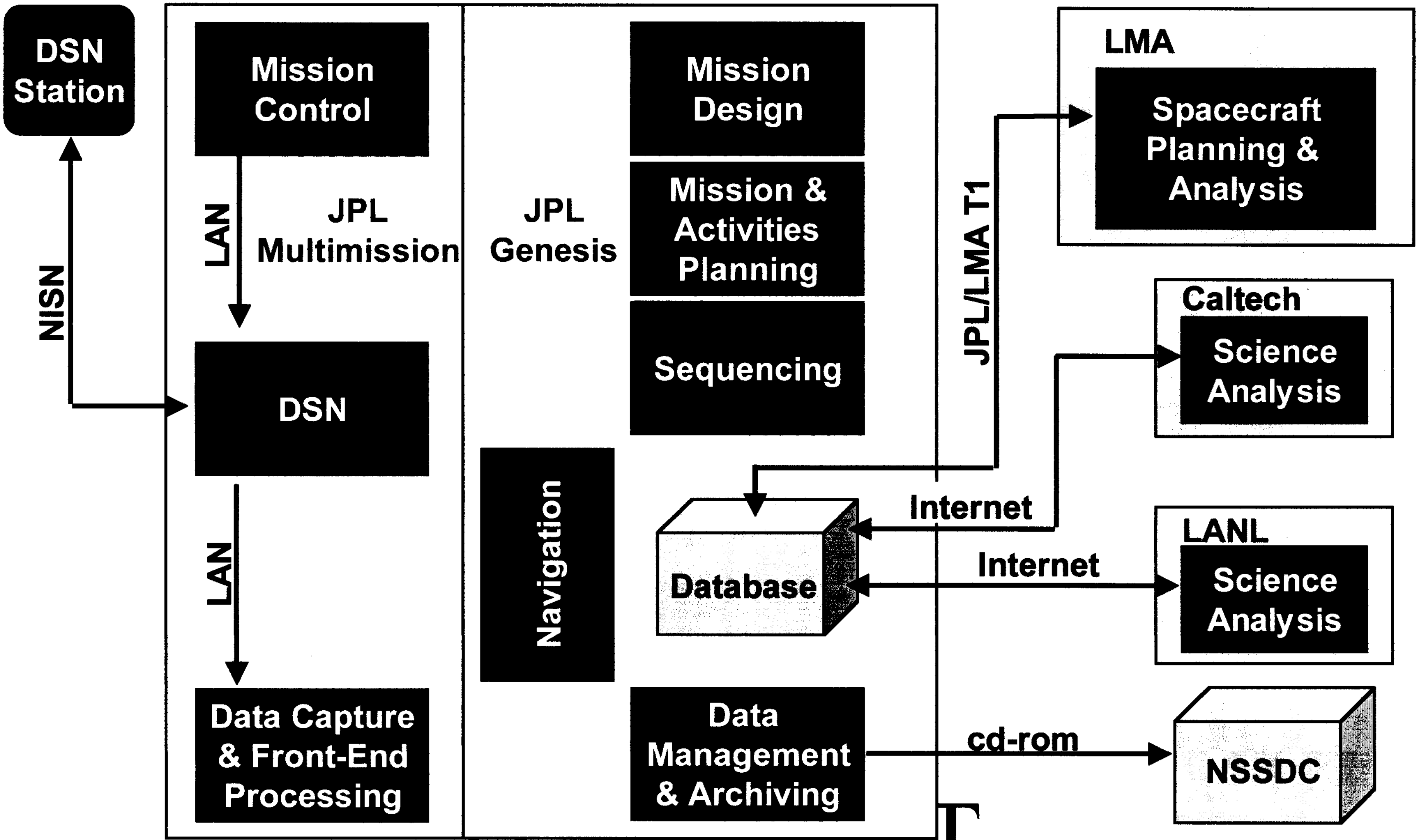
Overview
NOMINAL GDS ARCHITECTURE



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Odds & Ends

- Genesis is the NASA Selected Discovery 5 Mission
  - Principal Investigator: Dr. Don Burnett / CalTech
  - Project Management: JPL
  - Payload: JSC, Los Alamos National Labs, & JPL
  - Spacecraft: Lockheed-Martin Astronautics (Commercial Partner
  - Mission Ops: JPL, LMA, LANL
- Selected Competitively in December 1997
- Completed Preliminary Design Review (PDR) In July 1998
- Started Implementation Phase (Phase C/D) in August 1998
- Completed Critical Design Review (CDR) In June 1999

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PART 2

Science By A Non-Scientist

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Mission Objective

- To Collect and Return Solar Wind Materials and
- To Use It's Data To Address the Processes Involved in the Origins of the Solar System.

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Great Questions Addressed w/ Genesis Data

Examples of Major Planetary Science Questions for Which Genesis Will Provide Information

(1) How Can We Explain the Great Diversity of Planetary Objects?

(2) What Makes Earth Different From Its Planetary Neighbors?

(3) What Is the Sun Made Of? Are We Made of the Same Stuff?

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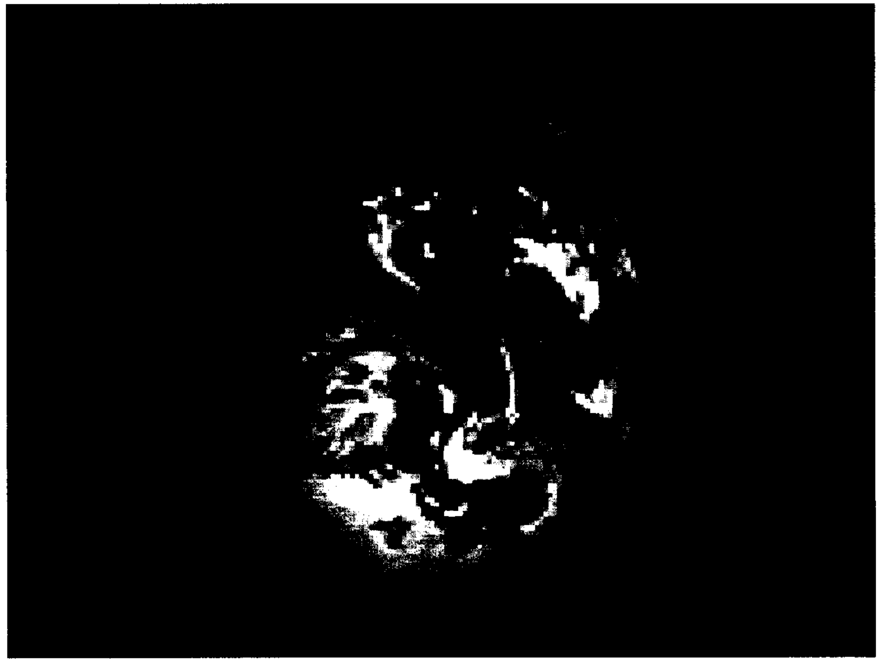
What Makes Venus and Earth Different?

Why Is Venus Hell?



And the Earth So Lucky?

- Venus Surface Temperature is 460 deg. C
- It's Dry As a Bone:

  Earth: $H_2O/CO_2 \approx 3$

  Venus: $H_2O/CO_2 \approx 10^{-4}$!!

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Fundamental Hypotheses

- The Diversity in Planetary Objects Is Primarily a Consequence of Conditions, Events and Processes in the Solar Nebula
- The Elemental and Isotopic Compositions of Planetary Materials Are a "Fossil-Record" of the Solar Nebula
- Solar Nebula Models Will Be Verified by Predicting Planetary Material Compositions Starting With a Solar Nebula Composition Based on Genesis Data
- Similarly, Genesis Isotopic Data Will Be Used to Verify Terrestrial Planet Atmospheric Evolution Models
- Solar Isotope Data (Especially O) From Genesis Test Whether 1-3 AU Materials Are the Same As in the Sun

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Science Collection/Measurement

- Measure Elemental & Isotopic Abundances of Solar Wind Ions.
  - Measurement Priorities
  - Accuracies or Precisions Required
- Collect Separate Samples for Each of 3 Solar-Wind Regimes: Low Speed, Coronal Hole, and Coronal Mass Ejections
  - Used to Determine Solar Photosphere Composition From Solar Wind
  - Necessitates Monitoring of Solar Wind Type By Spacecraft
- Provide a Reservoir of Solar Matter for Future Analysis
  - Sets Philosophy on Collector Area
  - Requires Long-Term Curation

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Prioritized Measurement Objectives

(1) O isotopes.
(2) N isotopes in bulk solar wind.
(3) Noble gas elements and isotopes.
(4) Noble gas elements and isotopes; regimes.

(5) C isotopes.
(6) C isotopes in different solar wind regimes.
(7) Mg,Ca,Ti,Cr,Ba isotopes.
(8) Key First Ionization Potential Elements
(9) Mass 80-100 and 120-140 elemental abundance patterns.
(10) Survey of solar-terrestrial isotopic differences.
(11) Noble gas and N, elements and isotopes for higher energy solar particles.
(12) Li/Be/B elemental and isotopic abundances.
(13) Radioactive nuclei in the solar wind.
(14) F abundance.
(15) Pt-group elemental abundances.
(16) Key s-process heavy elements.
(17) Heavy-light element comparisons.
(18) Solar rare earth elements abundance pattern.
(19) Comparison of solar and chondritic elemental abundances.

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Accuracies/Precision of Measurements

- **Elemental Accuracy (2 σ Limits)= $\pm$10% of the Number of Atoms of Each Element per cm^2 on the Collector Materials**
- **Isotopic Precision (2 σ Limits On the Relative Number of the Different Isotopes of an Element Compared to a Terrestial Reference Standard)**

– O, Mg, Ca, Ti, Cr, Ba	$\pm$0.1%
– C	$\pm$0.4%
– N	$\pm$1.0%
– Noble Gases	$\pm$1.0%
– ^{78}Kr, ^{124}Xe, ^{126}Xe	$\pm$3.0%
– Others	$\pm$1.0%

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Collector Materials

The Collector Materials Are the "Containers" Which Will Capture and Hold the Solar Wind Samples. Therefore:

- **Must Be Pure Enough:**
  - Design Goal Is Signal to Noise Ratio > 100
  - Critical Requirement SNR > 10
- **Must Be Clean Enough:**
  - Surface Contamination < 2 yr Solar Wind Fluence for any element
  - If Some Surface Contamination Does Occur, There Must Be Methods for Removing It Prior to Analysis
- **Must Lend Itself to the Desired Analytical Technique**
- **Different Materials Work Best for Different Elements**

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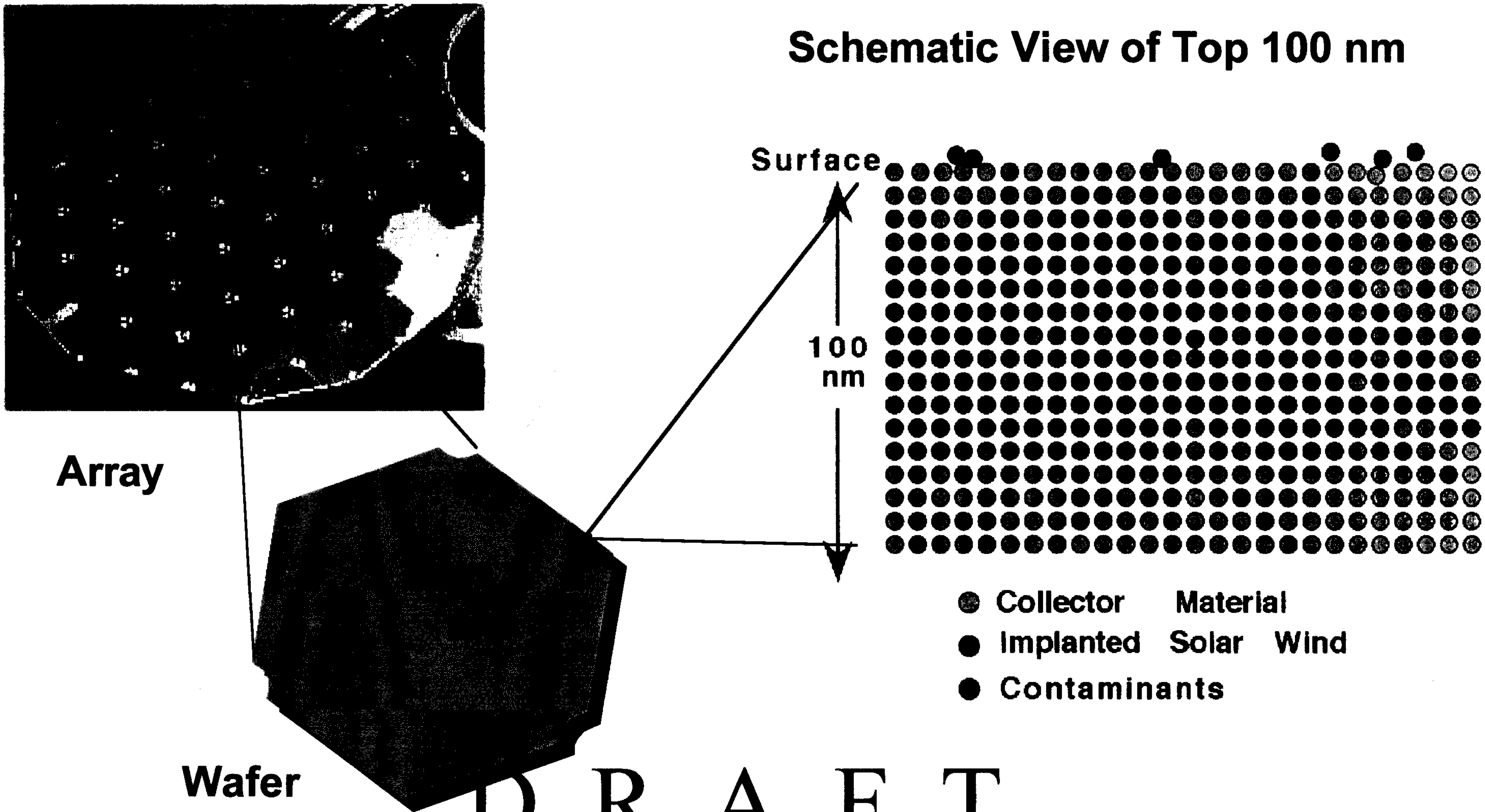
Contamination

Schematic View of Top 100 nm



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Material Selection vs. Measurement Objective

MATERIAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Diamond	CD	BD												CX				
SiC	CD	BD										CL		CX				
AuOS	C				BX	BX		B			BX						B	
AlOS			CD	CD														
SOS					CX	CX			D									D
Si	BD	BD			D	D	C	CL	CD	L		CX		B	CL	CL	CL	CD
Sapphire					BX	BX		CL	CX	L		CL		B	B	CX	CL	CX
Ge								CL	CX	L					CX	CX	CL	CX
Vitreloy			BX								CX							
Al			BD	BD					BD									
Pd on Pt													C					

C = Selected Material D = Documented Purity X = Planned, but not yet documented
B = Backup L = Objective with List of Elements; Partial Documentation

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Expected Solar Wind Abundances

Z	Element	Concentration (parts per million wt.)
3	Li	5.3×10^{-5}
4	Be	8.9×10^{-7}
5	B	3.1×10^{-5}
6	C	5.4×10^{0}
7	N	2.0×10^{0}
8	O	1.7×10^{1}
9	F	7.2×10^{-4}
	...	

Concentration of Solar Wind From 2-Yr Fluence Averaged Over Top 0.1 micron in Silicon

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Concentrator Design

- Average Concentration Factor for N and O Shall Be >20.
- Concentrator Target Area >15 cm^2.
- Concentrator Must Not Introduce $^{17}O/^{16}O$ Errors > 0.1%.
- Concentrator Target Temperature Not To Exceed 250°C.
- S.W. Ions Shall Be Accelerated > 8 kV Before Impacting the Concentrator Target.
- TBD %(Goal of 90%) of Solar Wind Proton Fluence Shall Be Prevented From Reaching Concentrator Target.

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Collector Array Design

- **Bulk Solar-Wind Collector Area > 0.6 m^2**
- **Each of 3 Special-Regime Collector Areas > 0.3 m^2**
- **Collector Array Materials Not To Exceed 200° C for Si and 250° C for Other Materials**
- **Material From Each Array Shall Be Uniquely Identifiable.**
  - **In Case Material is Dislodged**
- **Radioactive Nuclei Collectors Exposed in Lid of SRC.**

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Solar Wind Properties

- Solar Wind is Essentially Constant Velocity
  - Different masses have different energies and turn-around points
  - This is the source of mass fractionation.
  - Concentrator design now has energy independent focus
  - Simulated in test chamber by changing mirror electrode voltage with mass
- Group Velocity Varies Between 300-800 km/s
  - Mean velocity is ~440 km/s = 1 kev/amu
  - Coronal hole wind is significantly faster than other types
  - Ion monitor data used to optimize operation of H+ rejection grid and mirror point
- Ion Temperature Significant - Causes Spread in Velocity
  - Causes an effective angular distribution as seen by the concentrator
  - Concentrator has wide field of view

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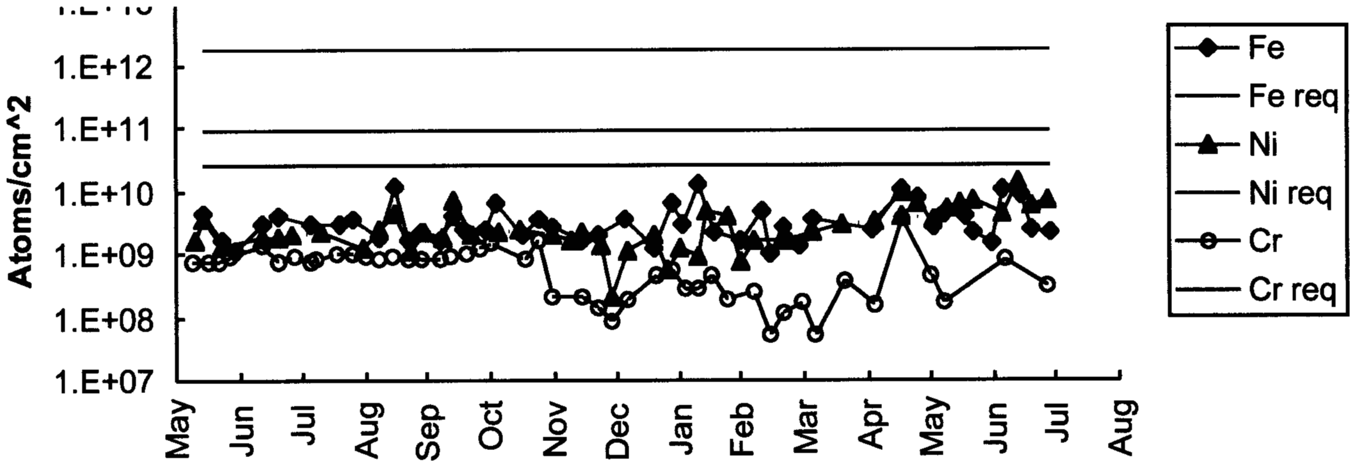
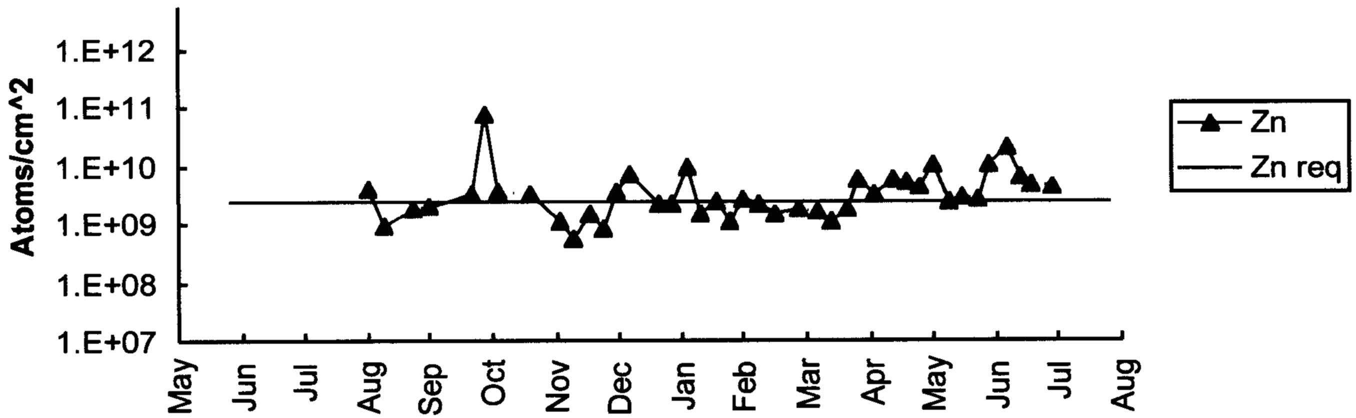
Start With Clean Collectors

- **We Can Consistently Meet or Exceed Requirements**

Example Process Control of Si Wafer Surface Contamination





~ 45% Of All Batches Meet Our Requirements

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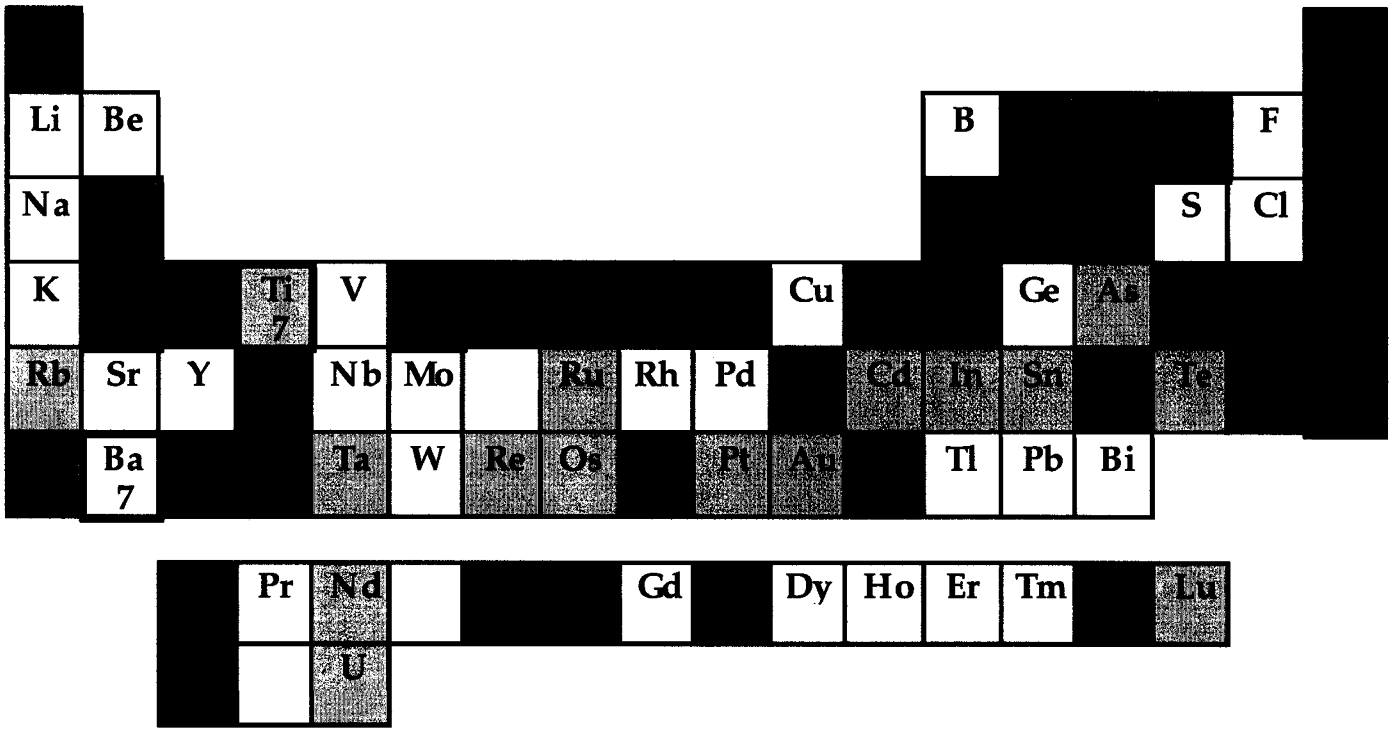
Bulk Purity of Elements*

*Bulk Purity in Collectors, Mostly Based on Silicon

- Green = SNR > 100
- Blue = SNR > 10
- Blank = SNR > 10 expected



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Sapphire-based Collectors Array Materials

Three forms of sapphire used in Collector Arrays:

1. Al and Au on Sapphire (AuOs, AlOS) (Objectives 2,3,4)
2. Bare Sapphire (Objectives 8,9,10,12,17,19)
3. Silicon on Sapphire (SOS) (Objectives 5,6)

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Concentration Factor

- Critical design requirement because grid and support structure obscuration must be minimized while aperture is maximized
- Optimized Efficiency vs. Size
  - C_{tot} = 43.4 (C - Geometric Concentration)
    x 91% (Percent Hitting Target, Worst Case)
    x 0.904^5 (Ions Traversing Grids)
    x 0.9 (Ions Traversing Support Structure)
    C_{tot} = 21.5
  - Ignoring overlap of ribs (would increase concentration)
  - Ignoring increased obscuration of curved grid (<<1%)
  - Worst case number includes some grid wrinkles, thermal changes, and scattering

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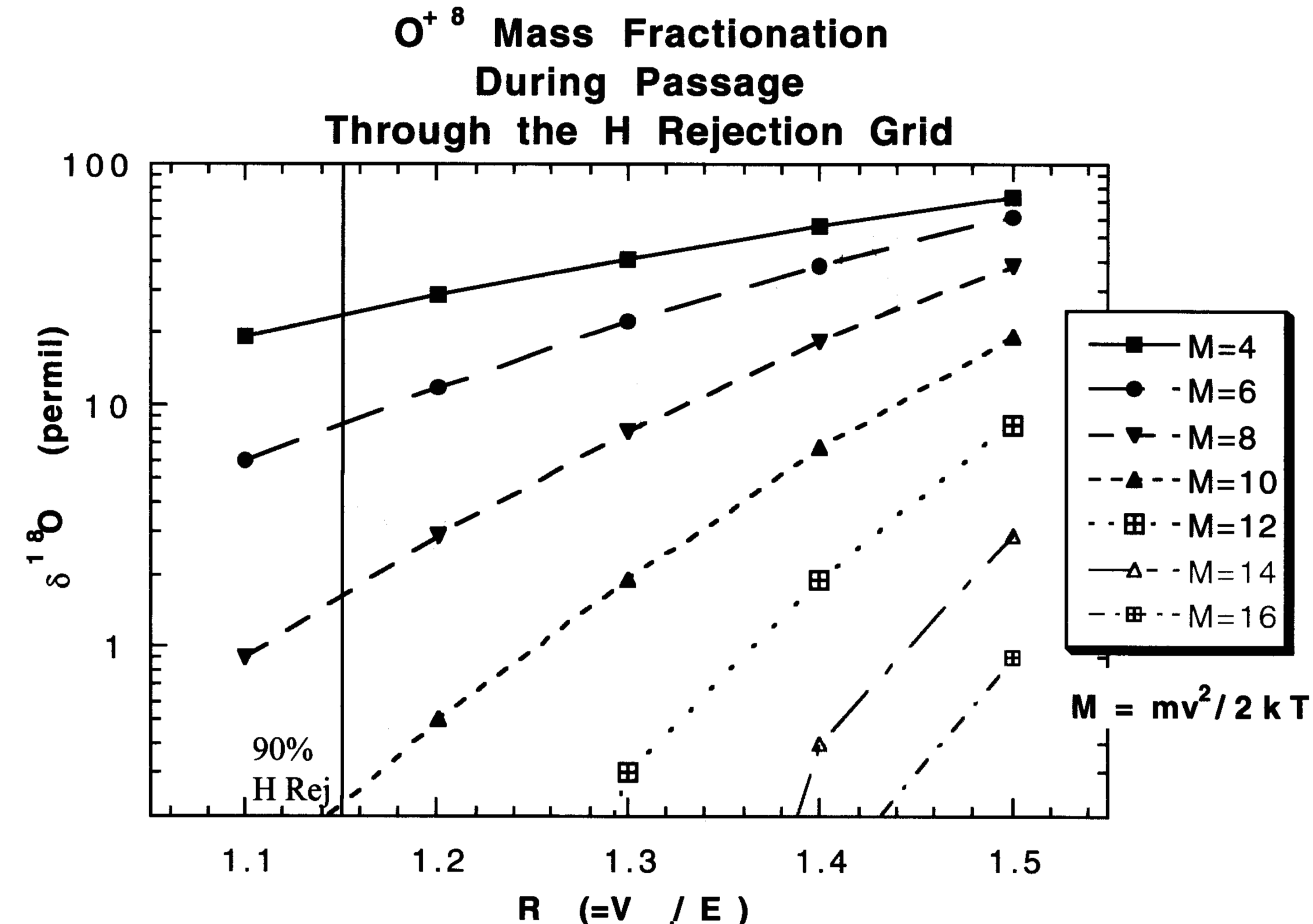
Mass Fractionation From H^+ Rejection Grid



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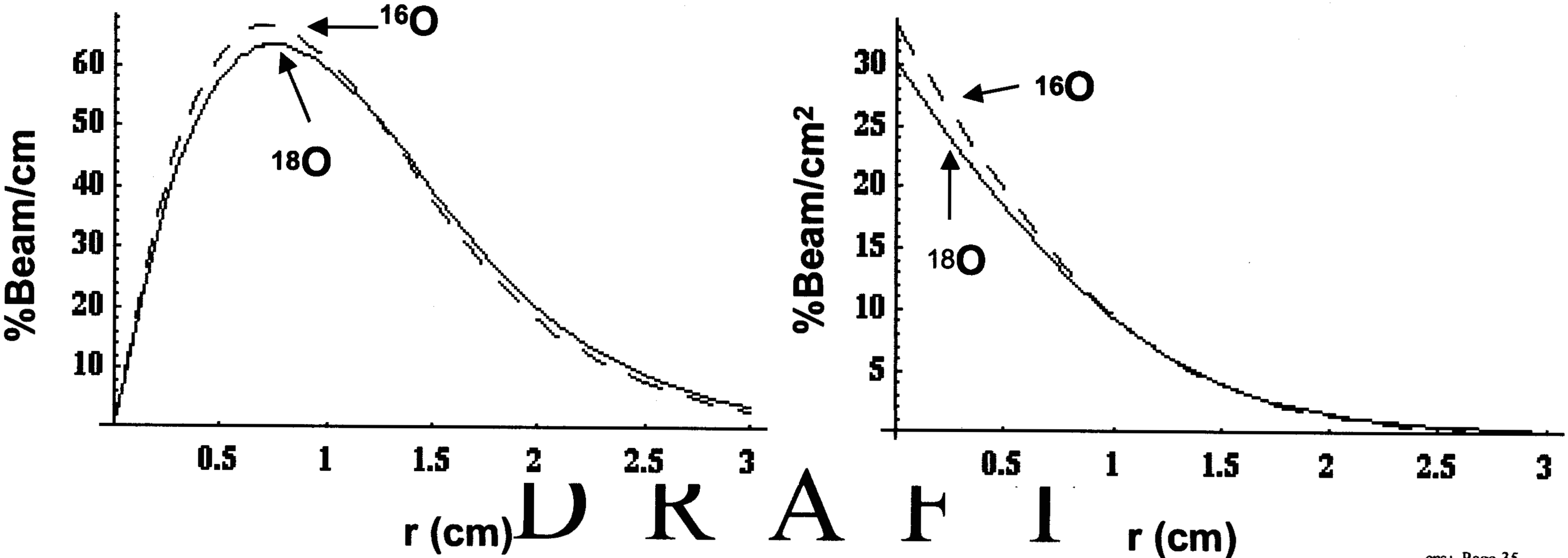
Total Mass Fractionation

- Overall Fractionation Slightly Favors ^{16}O (by < 1% Over ^{18}O)
- Fractionation Varies With Target Radius, But There is a Sweet Spot Between 1 and 2 cm Where Fractionation is Minimized. Uncertainty Requirement Will Be Met
- Local Fractionation Will be Tested Post-Flight Using Neon Isotopes

Oxygen Isotope Distributions As Fcns. Of Target Radius



Part 3
Treasure Hunting:
Sample Curation & Analysis

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Facility Instruments

- Advanced Analytical Instrumentation Development Is Required For the Accomplishment of Genesis Science Objectives,
- Plans are To Develop a Advanced Analytical Instrument Facilities (AAIF) Which Ensures That the Best Analytical Instruments Will be Used.
- "Facilities" Means Analytical Instruments Operated and Maintained by a Professional Staff at One Location but Available to NASA-Approved "User" Scientists for Specific Studies of Returned Solar Wind Collector Materials.
  - User Is Affiliated With the Research Program of a PI Approved by NASA's Planetary Materials and Geochemistry Discipline Science Program; and
  - Collector Materials Have Been Allocated to the User by the Sample Allocation Committee
- The Detailed Analytical Procedures for Specific Analyses Are the Responsibility of the User in Consultation With the AAIF Staff on Questions of Feasibility.
- The AAIF Staff Has the Responsibility to Maintain and Operate the Instrument at Peak Performance Levels and to Co-operate With Outside Users in the Actual Measurements.

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AAIF

- The Strawman AAIF Payload
  - One Large (3.5$m Capital Expenses), And
  - One Small (0.8 $M) Facility Would Be Established. The Actual Number And Size Would Be Decided By The Review Panel.
- The Strawman Facilities Are:
  - A State Of The Art SIMS (Secondary Ion Mass Spectrometer) With Multicollector Capabilities.
    - This Instrument Must Be Capable Of Making Oxygen Isotopic Measurements At The Designated Precision Levels.
    - Phase A Experience Shows That Methods Of Surface Desorption Of Background Molecules Other Than The Primary Sputter Ion Beam Will Very Likely Be Required.
  - A Zero-background RIMS (Resonance Ionization Mass Spectrometer) Facility Designed For High Sensitivity Elemental Analysis.

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Secondary Ion Mass Spectrometer (SIMS)

- This instrument would be essentially the year 2001 equivalent of the current Cameca 1270 instrument including multicollector capabilities which permit the simultaneous analysis of all isotopes of a given element. Such instruments are the flagships of modern materials analysis, and continued commercial developments are assured. Phase C/D studies by Col McKeegan with the UCLA 1270 will define the coupled transmission/mass resolution requirements for analyzing low elemental concentrations in the presence of interfering molecular ions from Si wafers. Most importantly, however, our experience with the Cameca 1270 during Phase A shows that an independent means of surface cleaning other than the primary sputtering beam is required for analysis of O isotopes (and elements such as F and Cl as well). This was anticipated in our Phase A proposal. Even under UHV conditions, background counts from contamination from the vacuum and from the surface of the sample being analyzed are observed. At present the only way to minimize this background source is with the primary sputter ion current itself. However, with the currents required to produce acceptable backgrounds for O, the solar wind implantation zone would be sputtered through in seconds. While such rapid data acquisition is conceivable with a multi-collector instrument and desirable if large areas are being analyzed, it is far better to have independent means to remove surface contaminants than the primary ion current. In principle this can be accomplished with tuned laser desorption of surface contaminant molecules. This concept will be tested in a collaboration with Chas. Evans & Associates in the first year of Phase C. The SIMS + laser instrument would not be available commercially. A special construction is required which would be significantly more expensive than the SIMS instrument alone (which, allowing for multi-collector capabilities, would cost roughly $2.5M, 1995), justifying the amount budgeted for our large facility.

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Resonance Ionization Mass Spectrometry (RIMS)

- **RIMS. Resonance Ionization Mass Spectrometry Will Be the Workhorse of the Genesis Elemental Analysis Program.**
- **In RIMS Very Thin Atomic Layers Are Removed by Sputtering or by Laser Ablation.**
  - **A Series (Probably at Least 3 for Genesis Work) of Highly Monochromatic Lasers Selectively Ionizes a Chosen Element and Nothing Else, Potentially Giving Very High Signal to Noise.**
  - **Moreover, Essentially All the Atoms of the Chosen Element Can Be Ionized (Ion Yields of Factors of 1000 to 10,000 Higher Than Sims), Giving RIMS Potentially Very High Sensitivity.**
- **Concept Development Work With Col's Pellin and Calaway During Phase C/D Will Produce a Design for a Suitable RIMS Instrument.**

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Sample Allocation Plan

- Except for the Early Science Return Experiments (Section 8), No Special Privileges Are Reserved for the Genesis PI or Cois.
- The Opportunity to Analyze Genesis Collector Materials Is Open to All Pis (Both US and Non-us) From the NASA Planetary Materials and Geochemistry Discipline Science Programs.
- Broad Access to State of the Art Instrumentation Capable of Collector Material Analysis Will Be Available Through the AAIF Program.
- The Inclusion of "Samples-only" Proposals, As Presently Done for Lunar Sample Access, Permits International Participation and the Use of US Instruments Other Than Those Identified As Genesis Facilities.
- Materials for Study Will Be Provided by the Curatorial Facility of the Johnson Space Center (JSC) Based on Recommendations of a Sample Allocation Committee (SAC).
- The SAC Also Serves As a Monitoring and Advisory Committee to the JSC Curatorial Facility on Issues Relating to Minimizing Contamination During the Handling and Storage of Collector Materials

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Analysis & Archiving of Monitor Data

- Data From the Solar Wind Monitors Will Be Returned to Earth on Approximately a Weekly Basis.
- The Data Will Be Examined to Track the Performance of the On-board Algorithms for Determination of the Solar-wind Regimes and Develop New Algorithms If Necessary.
- The Monitor Data Will Be Used to Calculate
  - (I) the Total Fluence of Hydrogen and Helium on Each Set of Collectors and
  - (Ii) Any Mass Fractionation Corrections to Be Made to the Analyses of Concentrator Samples.
- The Monitor Data Will Also Be Used to Place the Returned Samples in the Context of Solar-cycle and Other Variations in the Solar Wind.
- The Monitor Data Will Be Placed in the Relevant NASA Archive (Probably NSSDC) on a Continuing Basis Throughout the Mission. Documentation Concerning the Instrument Design, Performance, and Calibration Will Also Be Archived.

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